Production Systems

Pond Production Systems

Ponds are the oldest, most natural, and usually the most economical, production system for most aquaculture species. All production systems must be able to provide oxygen for the fish and remove toxic waste products produced by the fish. A pond's ability to accomplish these actions is based on naturally occurring processes and the fact that a pond is a small semi-closed ecosystem.

Oxygen production in a pond is primarily based on photosynthesis by the microscopic algae (*phytoplankton*) floating in the pond. Diffusion from the atmosphere contributes very little oxygen to a pond. The ability of a pond to reliably provide oxygen is the first limiting factor in the production capacity of ponds. Without aeration production is limited to approximately 1,500 pounds of fish per acre. With aeration provided production is increased to 4,000-6,000 pounds of fish per acre.

The other function a production system requires is removal of toxic waste products. When fish are fed prepared diets, much of the nitrogen in the feed protein is excreted through the fish's gills into the surrounding water in the form of ammonia. This ammonia is either removed from the water by the phytoplankton, or converted to less toxic forms by naturally occurring bacteria in the pond in a process known as nitrification. The efficiency of nitrification within the pond is currently the primary constraint on the production capacity of ponds for most species.

Types of ponds include watershed and levee style ponds. Watershed ponds are most practical in hilly areas and are constructed by building a dam across a draw or valley. Watershed ponds are sited so that the smallest dam impounds the most water. Because of hilly terrain, watershed ponds can be quite deep near the dam, affecting their use for species such as prawns. Construction prices vary based on terrain and dam size. However, one acre pond with drains should be constructed for $1,500-$2,500. Major considerations are suitability of soils, sufficient water supply based on watershed, ability to handle excess water during heavy rain and rainy periods, proximity to electricity for aeration, and accessibility for daily feeding and maintenance.

Levee style ponds are constructed in flat terrain by shallow excavation, then the soil is used to construct levees around all four sides. Leveed ponds have no watershed so a clean dependable water source must be available. Possible sources are streams or wells, which also allow better control over filling and draining. Leveed ponds are normally more productive per unit of size than watershed ponds because of shallow, uniform depth, and better manageability. Again, construction costs will vary based on location but should average less than $5,000 per acre with a drain.

Pond Construction Considerations

I. Site Selection

1. Pick the areas on your farm where you would most like to have your pond(s).
2. Do not select areas where runoff from feedlots will pollute your pond.
3. Do not select areas where crops are produced that may be sprayed with pesticides that can enter the pond in runoff after heavy rains.
4. Consider the possibility of poaching if the pond(s) are in a remote or secluded area.
5. Choose areas that are easily accessible with equipment, trucks, etc. during the time of year when the product must be stocked, harvested, etc.
6. Choose areas where the cost of running electric lines to the site would be the least expensive.
7. Choose areas close to emergency water sources (creeks, rivers, wells, other ponds etc.), if possible.

Of utmost importance, contact the **Natural Resources Conservation Service (NRCS)** office in your county and have them survey your locations and make recommendations. Also contact the KSU Aquaculture Program and ask to have one of the state aquaculture specialists review and make recommendations.

II. Construction Cost Factor

1. Terrain-Topography - Kentucky has a vast range of terrain and topography from mountains in eastern and southern to rolling hills through central to flat-“bottom-land” in western Kentucky. The terrain-topography, to a great extent, determines the type of pond that can be constructed, the maximum size that can be built and the amount of earth that must be moved.
2. Soils and soil characteristics - Kentucky soils are more varied even than the terrain and topography. For example, in Boone, Kenton, and Campbell Counties there are at least 5 different soil associations and 26 different soil series. Each soil classification has unique characteristics such as permeability and compactability, and while some soils are ideally suited for holding water, others will require installing a liner if a pond is to be built.
3. Contractors fees - There is a wide variation in fees charged by contractors. Factors such as a) the amount and type of equipment the contractor uses, b) prevailing wages of operators in different areas, c) the type of contracting the contractor normally engages in, d) the area in which the contractor is operating (e.g. rural areas vs. metropolitan areas), and e) knowledge and ability of the contractor in the art of pond construction. The NRCS in each locality maintains a list of contractors who build ponds.

5. Ponds used for aquacultural purposes will need to be fenced off from livestock. A watering troughs for livestock must be positioned below the pond. The pond will need piping and valves to control the water level and to drain the pond from time to time. Electric lines for the use of an aerator, and roadways for access to the ponds during inclimate weather, may also have to be laid and constructed.

III. Recommendations

Upon surveying the possibilities for pond sites on your farm, call the NRCS in your county and/or the KSU Cooperative Extension Service and request their assistance in locating the best site for your pond. Once a site is selected and staked out, then contractors can be contacted for bidding. Contact the NRCS office in your area for their list of contractors, or better still, talk with neighbors, friends, etc. who have had ponds dug and get references in this manner. If possible, inspect some of their work. Due to the fact that they don't know what they will hit once the top soil is removed, most contractors will not quote an exact price for the completed job. Most will, however, give an estimate. If absolutely forced to give an exact price, they will make the price high enough to cover the worst of possibilities. It is, therefore, of utmost importance to select a contractor known for his ability, honesty, and integrity.

Currently, in Kentucky, contractors are charging from $2.00 to $4.00 per cubic yard to move dirt with a bulldozer, and hourly rates for dozers are $10.00 to $12.00 times the size of the dozer (caterpillar) per hour (i.e. a D-5 is $50.00 to $60.00 per hour; a D-6 is $60.00 to $72.00 per hour etc.).

Laser-guided, tractor-drawn dirt pans are used in Mississippi and other areas including the purchase area in Kentucky. Contractors using this equipment have been charging from $.70 to $1.00 per cubic yard to move dirt and construct levee ponds.

Do not forget to figure the costs of roads, electricity, fencing, and piping in the total costs. Also, remember that each acre of water contains over 325,000 gallons of water for each foot of depth. Make sure your piping and valves are of sufficient size to remove that much water in a sufficiently short time.

Reservoir Ranching Production Systems

Reservoir ranching is an extensive (low input) aquacultural production system where young fish are stocked into a reservoir, permitted to forage on the natural food supply, and harvested after a period of time. This is a very economical system for fish production, which uses existing reservoirs that were primarily developed for the storage of water, flood control, and hydroelectric purposes. It is used throughout the world, especially in China, the former U.S.S.R., and African countries, to increase inland fisheries production.

Fish most suitable for reservoir ranching are filter feeders, such as paddlefish, bighead, and silver carp. They feed primarily on minute organisms, such as zooplankton, which are naturally present in the water. Therefore, special diets and intensive management are not needed. Fish yield can vary from reservoir to reservoir, depending on the fertility of the water. In China, production of filter-feeding fish stocked into reservoirs averages about 200 pounds per acre. If this production system is adopted in the commonwealth, up to 48 million pounds of fish could be produced in Kentucky reservoirs (240,000 acres available).

KSU has been evaluating the potential in reservoir ranching paddlefish in Kentucky. KSU has recommended that fingerlings should be large enough at stocking (greater than12 inches) to avoid predation; barriers should be installed at spillways and at streams and river inlets to prevent fish from escaping, and the fish should be harvested with entanglement gear such as gill nets when water temperatures are below 50°F (late fall, winter, and early spring) so that fish harvesting does not interfere with public use of reservoirs.

Cage Production Systems

It is not clear when people first used cages to grow fish. It is likely that cages were first used by fishermen to hold captured fish until they could be sold to market. The first documented cages were used in Southeast Asia in the 1800s as a means of growing fish for food and were made of bamboo. Cage culture in the United States began in the 1950s with the production of plastics used for the construction of cages. Many countries in Southeast Asia and Europe use cages to grow fish. In the U.S., cage culture is mainly limited to freshwater ponds and lakes; however, in other countries, fish are grown in freshwater as well as in the ocean. Large cages, called net pens, are placed into the ocean and used to grow marine fish. These net pens often can hold more than 5000 pounds of fish per cage.

The culture of fish in cages is a method for some farmers to grow fish in ponds that may otherwise be unsuitable for aquaculture. Many ponds in Kentucky have irregular bottoms, are too deep (greater than 7 feet), or have obstacles (e.g. stumps) that preclude them from use in standard aquaculture production systems, which require the pond to be seined. However, by growing fish in cages, these ponds may be utilized. The advantages of using cages to grow fish are use of existing ponds that are currently not utilized, ease of feeding, ease of stocking and harvesting, and less expense associated with treating or preventing diseases than free swimming fish. Disadvantages are more stressful conditions for some fish species, the possibility of rapidly spreading diseases, more susceptibility for a fish-kill due to low oxygen conditions, and the economic life of cages, which may be as low as 3 years, depending upon local conditions.

From the research conducted at the cage culture facility at KSU, numerous fish species that appear to be satisfactory for cage culture in Kentucky during the summer growing season. These include channel catfish, blue catfish, hybrid catfish, hybrid striped bass, and hybrid bluegill. However, since the growing season in Kentucky is shorter than for the more southerly states, a second-year of culture may be required. While it appears that channel catfish and hybrid striped bass can be over-wintered in cages, blue catfish should not be. Extremely high mortalities occur in February through April when blue catfish are grown in cages; and thus, it is recommended that blue catfish be harvested from the cage or transferred to ponds in the Fall. Rainbow trout appear to be suitable for growing in cages in the winter (Wynne 1992).

The size of the cage used will depend upon the preferences of the farmer, the level of production desired, and the size of the pond. However, a convenient size cage is a rectangular unit that measures (4' W x 4' D x 8' L; 3.75 m^3). It is recommended that farmers stock a small number of fish per cage until they learn the “art” of culturing fish in cages. Production rates for cages can be 200-300 pounds per cubic meter or higher. Total production of 1500 to 2000 pounds per acre of pond may be possible. However, a great deal of the final production depends upon the species grown, the diligence of the producer, and the size of the pond. The use of aeration and/or water circulation devices may be very beneficial to the farmer when growing fish in cages and is strongly recommended.

Cage production of fish is possible for producers who are interested in utilizing ponds that may be unsuitable for typical pond aquaculture; however, extreme care and hard work is required to produce fish in cages. County agents and appropriate extension personnel should offer all the assistance that the producer may require to ensure a successful harvest.

(See appendix for recommended readings on Cage Production)

Raceway and Flow-through Fish Production Systems

In Kentucky, year round commercial trout culture occurs in steel-reinforced, concrete raceways. Raceways have a length to width ratio of approximately 6:1 and hold a water depth of 3 to 4 feet. Typically, raceways are built in pairs and share a common interior wall. Raceways that are 36 feet by 6 feet may have a floor and walls that are 6 inches thick. Larger units may be constructed of poured concrete 8 inches or more in width depending on raceway length and water volume. Trout production is limited by the availability of large freshwater springs which provide gravity-fed water to the raceways in adequate quantity. Large volumes of water must flow via gravity through a series of terraced raceways and are discharged into a receiving stream with little or no wastewater treatment.

Aeration occurs between raceways as the water flows over a screened outfall and pours into the head of the raceway below. Water volume is exchanged approximately every hour. The cost of pumping such large volumes of water (400-4,000 gallons per minute) would be prohibitive in most cases. Nitrogenous wastes are removed from the raceways by flushing or dilution before toxic levels of ammonia gas can concentrate in the water. Alkalinity (greater than 100 milligrams per liter) and pH (7.5) generally limit the serial reuse of Kentucky’s well buffered limestone spring water to 6 to 8 raceway passes. The water flow rate, water chemistry, temperature, size of fish, and the rate of feeding determines the volume of fish which can be produced in a particular raceway system. Generally, rainbow trout can be grown at a rate of 25-50 pounds annually per gallon per minute of water flow.

Flow-through, or single use raceways and circular tanks, are often used for hatchery rearing of fry and juvenile warm-water fish such as largemouth bass, channel catfish, and hybrid striped bass. For short durations, it is economically feasible to pump relatively little water into a raceway or tank given the small volume of fish that are consuming small quantities of feed. Normally, after these fish are feed trained or have reached a certain length or weight, they are stocked into earthen ponds. Potentially, larger warm-water fish could be grown in flow-through raceways which were supplied with a free or inexpensive water source. However, such situations are not common.

Raceways and tanks are commonly used for temporarily holding bait minnows and all sizes and species of fish. Rectangular raceways or holding tanks fit well in buildings and provide easy access to the fish for the purposes of size grading and harvesting. However, raceways are expensive to construct, require maintenance, and must be dredged periodically to remove sludge. Circular or square tanks are made of a variety of materials and can be less expensive than concrete raceways or holding tanks. Circular tanks with conical floors and centrally located stand-pipes (equipped with venturi sleeves) tend to do a better job of removing sludge. However, circular tanks require more space in rectangular buildings than raceways and are more difficult to grade or harvest from.

Recirculating Production Systems

A recirculating system is the most intensive system of fish production. This system through water treatment and water reuse can utilize less than 10 percent of the water required by ponds to produce similar fish yields. Many fish species grown in ponds, raceways and floating pens could be reared in commercial-scale recirculating systems. Therefore, with increasing concern for resource conservation and demand for high quality aquacultured products, there is a great deal of interest in recirculating systems in the United States and other parts of the world. Though there have been a few reports of profitable commercial-scale recirculating systems, economic viability of growing most commonly cultured species in these systems has not been proven. Recirculating systems have generally been expensive to build. These systems will not be used on a wide scale basis until total cost of producing fish is comparable to the cost of production in ponds and other similar systems. The challenge to designers of recirculating systems is to develop systems that maximize production capacity per unit of capital invested but will maintain reliability of the controlled environment. Currently, recirculating systems have a great value in educational and research labs.

The major advantages in using recirculating aquaculture systems are 1) low water requirements, 2) low land requirements, 3) the ability to control water temperature, 4) the ability to control water quality, and 5) independence from adverse weather conditions. Therefore, the aquaculturist has the ability to measure and control most variables which make up the environment of the recirculating system and maximize fish production per unit.

Good water quality is most important in maximizing fish production in a recirculating system. Critical environmental parameters in the water of the production system include the concentrations of dissolved oxygen, un-ionized ammonia-nitrogen, nitrite-nitrogen, nitrate, carbon dioxide, pH, and alkalinity. By-products of fish metabolism include carbon dioxide, ammonia-nitrogen, particulates, and dissolved fecal solids. In recirculating tank systems, proper water quality is maintained by pumping tank water through specialized filtration and aeration equipment. Water treatment components must be designed to eliminate the effects of these waste products as well as work in conjunction with the total system.

Numerous technologies are available for recirculating systems. However, there are four basic components to these systems: solid waste removal, ammonia- and nitrite-nitrogen control, dissolved gas control, and disinfection. Solid waste includes settleable and suspended solids. Settleable solids sink to the bottom of the tanks and are siphoned and discarded from the system. Suspended solids are removed with screen or sand filters. Ammonia and nitrite-nitrogen control is accomplished with a biofilter that relies on bacteria to remove these nitrogenous waste products. Some of the common biofilters are rotating biological contactor (RBC), expandable media filters, fluidized bed filters, and packed tower filters. Dissolved gas control involves adding dissolved oxygen and removing carbon dioxide. Some common dissolved gas components include diffuser aeration, mechanical aeration, packed column aerators, counter current diffusion column, pressurized spray tower, and pressurized packed column. The last component to be considered for a recirculation system is disinfection of pathogenic organisms which can be accomplished with ozone or ultraviolet irradiation.

Most reports of successful production have been from small (less than 100,000 pounds per year), recirculating systems supplying fish to local niche markets at high prices. These high priced markets are necessary for financial success because of high cost of fish production in recirculating systems. Typically, the fixed cost of developing a recirculating system is higher than that for an equivalent pond production system. Given this fact alone, a producer should not try to compete with pond raised products. Instead, the producer should target high value markets, such as gourmet food, tropical or ornamental fish, or year around supply of fresh product. As with other aquaculture production systems, the size of the recirculating system and decision to become involved should be market driven.